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ABSTRACT

The conceptualization of memory as consisting of a collection of attributes was explored. Underwood's (1969) work on attributes of memory was reviewed. Following this, several paradigms for further research were suggested. One research paradigm dealt with individual differences and memory attributes. It was suggested that individuals may differ in the extent to which they develop or utilize certain types of attributes. A second research paradigm dealt with the types of organization imposed by a subject during the learning of a list of verbal items. Finally, some selected research on second-order storage and retrieval plans was reviewed. Implications of research on memory attributes for education were discussed. (Author)

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MEMORY ATTRIBUTES: SOME DIRECTIONS FOR FURTHER RESEARCH AND IMPLICATIONS FOR EDUCATION

REPORT FROM THE SITUATIONAL VARIABLES AND EFFICIENCY OF CONCEPT LEARNING PROJECT

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MEMORY ATTRIBUTES: SOME DIRECTIONS FOR FURTHER RESEARCH AND IMPLICATIONS FOR EDUCATION

By Elizabeth Schwenn Ghatala

Report from the Situational Variables and Efficiency of Concept Learning Project

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The Wisconsin Research and Development Center for Cognitive Learning focuses on contributing to a better understanding of cognitive learning by children and youth and to the improvement of related educational practices. The strategy for research and development is comprehensive. It includes basic research to generate new knowledge about the conditions and processes of learning and about the processes of instruction, and the subsequent development of research-based instructional materials, many of which are designed for use by teachers and others for use by students. These materials are tested and refined in school settings. Throughout these operations behavioral scientists, curriculum experts, academic scholars, and school people interact, insuring that the results of Center activities are based soundly on knowledge of subject matter and cognitive learning and that they are applied to the improvement of educational practice.

This Theoretical Paper is from the Situational Variables and Efficiency of Concept Learning Project in Program 1. General objectives of the Program are to generate new knowledge about concept learning and cognitive skills, to synthesize existing knowledge, and to develop educational materials suggested by the prior activities. Contributing to these Program objectives, the Concept Learning Project has the following five objectives: to identify the conditions that facilitate concept learning in the school setting and to describe their management, to develop and validate a schema for evaluating the student's level of concept understanding, to develop and validate a model of cognitive processes in concept learning, to generate knowledge concerning the semantic components of concept learning, and to identify conditions associated with motivation for school learning and to describe their management.

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I
INTRODUCTION

REVIEW OF THE ATTRIBUTES OF MEMORY

A recent paper by Underwood (1969) has advanced the notion that a memory consists of a collection of attributes which serve to discriminate one memory from another and to act as retrieval mechanisms for a target memory. Other papers by Bower (1967) on the multicomponent memory trace and by Wickens (1970) on encoding processes in short-term memory have dealt with much the same conceptualization. According to Underwood,

> When memory is conceptualized as consisting of an ensemble of attributes, memory for an event per se has no psychological meaning because a memory without attributes is incapable of being remembered (retrieved). There is no "corpus" which can be recalled directly. Furthermore, differences in attributes for different memories are fundamental for discriminating or differentiating memories, hence are fundamental for understanding the failure of S to perform perfectly on a retention test, i.e., for understanding forgetting. [1969, p. 559]

Underwood then went on to identify attributes which are involved in the memory for verbal units. The evidence for these attributes is derived mainly from the verbal-learning laboratory.

The basic notion is that as a S learns material he is establishing attributes which serve as the long-term memory for the material. The process of establishing memory attributes can be called encoding. Presumably, the attributes which are established depend on the material to be remembered, the nature of the task in which the material is presented, and on the conditions under which the material is presented. Some of the attributes identified by Underwood are discussed briefly below.

The memory of an event may carry a temporal attribute, since the perception of an event occurs at a given point in time. Underwood cites Yntema and Trask (1963) as having shown that Ss can make reliable temporal discriminations for items presented early and late in a series. They concluded that a memory carries a time tag. Other evidence (Underwood & Freund, 1968) suggests that temporal discrimination may drastically reduce the interference between two lists.

When one cannot recall a particular fact about which one has read, it is not unusual that one can recall the position of that fact on a page in a book. That is, a memory may carry a spatial attribute. Serial learning may well involve the learning of a spatial attribute for successive words in a list.

Evidence for a frequency attribute which is independent of associative strength is also presented by Underwood (1969). Subjects can judge quite accurately the frequency with which different events have occurred. These judgments are mediated by a frequency attribute which exists as a component of the memory for such events.

Material may be presented for learning by auditory signals or by visual signals. The question is whether a memory can carry a modality attribute which permits discrimination of memories for stimuli presented in different modalities. There is evidence that retroactive inhibition (RI) is reduced if the original and interpolated lists are presented by different modalities (Inoue, 1968). Wickens (1970) has shown release from proactive inhibition (PI) after switching modalities in short-term memory experiments.

The work by Brown and McNeil (1966) on the "tip of the tongue" phenomenon is cited by

Underwood to indicate that memory for a word may include an orthographic attribute. Essentially this phenomenon consists of Ss being able to correctly characterize words which they cannot recall as to the number of syllables and the initial letters.

The memory for a letter, syllable, word, or series of words may carry an acoustic attribute. One could argue that this attribute, at least in hearing Ss, is always present. As Underwood points out, however, the question is whether the acoustic attribute plays a discriminative role in memory. Work in short-term memory (Conrad, 1964) shows the acoustic attribute to play a dominant role with low-meaningful material. That is, interference in short-term memory with low-meaningful material is predominantly acoustic interference. With material of high meaningfulness, other, more dominant, attributes may limit the role of the acoustic attribute.

Another attribute which functions to discriminate memories within a modality is the visual attribute which consists of images. A S may encode words to be learned by representing each with an image of the object symbolized by the word.

Words may be associated with certain nonverbal affective responses. A memory, therefore, may consist in part of an affective attribute. When an affective attribute is defined by dimensions of the semantic differential, effects on memory are demonstrable (Wickens, 1970).

Since a memory may carry information about the context in which the memory was formed, Underwood has identified a contextual attribute which may serve directly as a discriminative attribute of a memory.

When a word is presented, it may elicit implicit associative responses which then become an attribute of the memory for that word. For a specific word in a task the attribute is usually identified as the overt response produced in word-association procedures. Thus the associative attribute might consist of an antonym or a synonym.

A word might also elicit a superordinate term or concept name which then becomes part of the memory for the word. This can be called a conceptual attribute. The conceptual attribute occurs by an associative process; thus, this attribute may be considered a special case of the associative attribute.

The above are some of the attributes, identified by Underwood, by which Ss may encode verbal units. They are the cues which Ss use for later retrieval and discrimination of the memories for these units.

Some implications of viewing memory as a collection of attributes are outlined by Underwood. The first of these is that when measuring memory one must consider the nature of the attributes making up a memory and also the attributes emphasized on the retention test. The more consonant these are the higher will be the measure of retention. A second implication is that whenever one or more attributes are a part of two or more different memories, interference may occur in recall. The greater the number of different attributes making up a memory, and the less these attributes are parts of other memories, the less the interference. A third implication is that once learning has occurred, attributes may be forgotten at different rates. One other implication or speculation is that the attributes which are established as a memory during learning may differ as a function of the developmental stage of the S.

PURPOSE OF THE PAPER

Underwood's statements regarding implications of his theory are directions for future research on the memory process and its converse, forgetting. The purpose of the present paper is to explore added directions which this research might take. More specifically, the interest is in exploring research paradigms which could be developed within the conceptualization of memory provided by Underwood, which might possibly be applied to instruction in schools.

The following sections of the paper represent only the author's first attempt to outline some areas of research which might be fruitfully approached in the attempt to relate the conceptualization of memory as a collection of attributes to the instructional process. The first of these sections deals with individual differences in the development of memory attributes. It seems obvious that this is one area that must be explored if application is ever to be made to education. It also seems obvious that research paradigms aimed at revealing applications to education must deal with Ss' memory for events larger and more complex than the verbal unit. As a first step in this direction, the second section deals with a research paradigm for studying encoding strategies utilized by Ss in learning lists of verbal items. In the third section, selected literature related to higher-order storage and retrieval plans is reviewed. In each section there is no attempt to cover all relevant literature. Indeed, the vastness of the topics

precludes any but the most superficial treatment. Rather, the strategy in the sections to follow will be to explore the seminal ideas of one or two researchers in each area which seem to offer a fruitful starting place or framework for research on memory attributes as related to each topic. The research paradigms suggested in the first two sections of the paper involve laboratory tasks and settings. Thus, the present paper is not an attempt to make direct application to classroom learning. If, however, these paradigms prove to be fruitful in the laboratory, such applications will be a step closer.

II

INDIVIDUAL DIFFERENCES AND MEMORY ATTRIBUTES

REVIEW OF SELECTED LITERATURE

When considering individual differences (IDs) in learning and memory, one can make the distinction as does Jensen (1967) between intrinsic and extrinsic IDs. Individual differences which are extrinsic to the learning process are such things as differences in IQ, age, achievement, personality differences,and so on. Many studies have been done and will continue to be done in which Ss are separated or stratified on such extrinsic variables and are then tested for differences on process variables related to learning and memory. A study recently conducted by the author (Ghatala, 1970) on differences in memory attributes as a function of age is an example of this type of study. There are usually two rationales for following the above procedure. First, the Ss are stratified on an extrinsic variable in order to reduce error variance. That is, the stratifying variable is of little interest in itself. A second reason for introducing such variables into a study is that theory concerning the process under study predicts a lawful relationship between certain subject characteristics and performance on certain tasks. In this case, the extrinsic difference between Ss is directly related by means of theory to an instrinsic difference in the process which should be related to performance on learning or memory tasks which are sensitive to such differences. Some good examples of this second case are Spence's (1956) work on anxiety and conditioning and Eysenck's (1953) work on introversion-extroversion as related to learning. In the author's recent study on age and memory attributes, the age variable was presumed to be related to the availability of verbal-associative encoding habits. It was predicted that younger children would have relatively fewer and less stable associative and conceptual responses to verbal units and thus would not spontaneously develop these attributes within a learning task as strongly as would older children.

Another approach to IDs as related to learning and memory is to look directly for intrinsic differences in the process itself. This approach, as exemplified by psychometricians like Guilford (1967) who are interested in exploring the nature of intellectual and cognitive abilities through factor analysis, has been rather divorced from the experimental tradition in which the study of learning and memory has proceeded. Recently, Jensen (1967) has attempted to adopt this approach in the study of IDs in the learning process. Jensen proposes a taxonomy of IDs in learning based on a three-dimensional classification system. One dimension is the type of learning task (conditioning, rote learning, discrimination, etc.); another dimension is content of task (verbal, numerical, spatial—this dimension also includes modality); and the third dimension is procedures employed in the tasks which may vary (pacing, distribution of practice, intra-task similarity,etc.) The result of such a classification system is a myriad of tasks which differ on the surface, i.e., phenotypically, from one another. Jensen's basic notion is that Ss differ on a relatively few underlying (genotypic) learning processes. Differences in these genotypic processes will account for the patterns of intercorrelations found among tasks. Jensen's strategy in finding such genotypes is to concentrate on only one or two cells generated by the classificatory system in any one study or studies. By keeping constant as many sources of variance as possible while manipulating a narrow range of variables, he hopes to generate sets of intercorrelations which reveal the underlying genotypes. The sheer amount of labor involved in such an undertaking is staggering to contemplate. Theory concerning the nature of underlying genotypes should prove helpful in directing and limiting the search for IDs.

PARADIGM FOR RESEARCH

Taking one slice of Jensen's taxonomy, that dealing with rote-learning tasks with verbal content, one could start with the theoretical notion that Ss differ in the readiness with which they develop different types of memory attributes within such tasks. To explore IDs in memory attributes, Ss could be given a variety of different tasks or the same task under different conditions which might be expected upon logical analysis to require the development of the same or different attributes. Then the Ss' performance across tasks could be studied. Various types of intercorrelations between tasks might be expected. For example, the tasks in such a battery might include a verbal discrimination task, a frequency judgment task, a serial learning task, a task in which Ss have to remember the relative position of items in a series, a false recognition task, a free recall task in which the input list is organized into concept clusters, and another verbal discrimination task in which the word designated as correct in each pair elicits the wrong response of another pair within the list. Now, if Ss differ on the attributes they develop in learning such tasks, and if the performance on such tasks reflect this difference, then various patterns within Ss across tasks should become apparent. Thus, if the development of a differential frequency cue is the critical attribute in learning a verbal discrimination list (Ekstrand, Wallace, & Underwood, 1966), then Ss who are more sensitive to such cues, i.e., they perform well on a frequency judging task, should do better on a verbal discrimination task than Ss who are less able to utilize such attributes. Subjects who spontaneously develop strong verbal-associative attributes within a learning task should have high clustering scores on the free-recall task and more false positives on a recognition task involving verbal associates (Underwood, 1965) than Ss who do not develop these attributes as strongly during learning. Moreover, the former type of S should have more difficulty on a verbal discrimination list with crossed associates since the verbal-associative attribute in this case interferes with the development of the differential frequency cue. If an important attribute developed in serial learning is a spatial attribute or a temporal attribute or some combination of these, then Ss who demonstrate a facility in developing such attributes as determined by their performance on a series-position judgment task (Underwood, 1969) should show better performance on a serial-learning task than Ss not demonstrating such an ability.

Additional tasks or perhaps tasks better suited to the purpose than the ones suggested here, can probably be generated. However, the above suggestions do demonstrate the basic notion of such studies—to search for patterns of performance across tasks which are presumed to reflect the development of different attributes.

There are, of course, problems involved in such studies. One is the matter of finding tasks with suitable reliabilities so that significant intercorrelations among tasks can be found. The reliabilities of learning measures have not often been considered in the verbal-learning laboratory. Another problem is to find tasks which reflect the development of a single attribute. This may prove a formidable obstacle, but one could start by eliminating obvious obscuring factors. For example, if one is interested in the development of spatial-temporal attributes in serial learning, one would not use lists constructed of nonsense syllables since this would add a response learning component to the task, obscuring the development of spatial-temporal attributes.

Suppose that such studies were carried out and reliable and identifiable patterns of IDs in encoding were found. What implications would this have for education? For one thing, basic differences among Ss in learning would have been demonstrated. Whether these differences are truly basic differences or whether they are reflections of differences in more basic processes would be open to question. Nevertheless, one would expect, if such differences in encoding exist, that they would in turn be related to performance on school tasks. These relationships are liable to remain obscure, however, until school tasks are subjected to the same kind of analysis and classification suggested by Jensen's taxonomic system for laboratory tasks.

When various authors (e.g., Cronbach, 1967) speak of tailoring instruction to accommodate individual differences, they must mean to imply that we can identify those basic individual differences in the learning process to which variations in instructional procedures can be practically geared to produce substantial improvement in school achievement for large numbers of students. Unfortunately such information is sorely lacking. Hopefully, the approach suggested here, among others, can eventually lead to such knowledge.

III

MEMORY ATTRIBUTES AND ORGANIZATION

The central problem in learning material so that it can later be recalled is the development during learning of memory attributes which will result in the accurate retrieval and discrimination of information upon demand. This section will be concerned with research on the development of encoding strategies and the relative efficiency of encoding strategies in long-term retention with a view toward the possibility of instructing Ss in the development of efficient encoding strategies. Or, to put this another way, can retention be improved by teaching Ss to develop memory attributes which will result in better retrieval and discrimination of memories? To answer this question research paradigms must be developed which will allow the identification of encoding strategies and the comparison of the relative efficiency of such strategies for long-term memory. That is, before we can instruct Ss in the use of efficient strategies we must first find out what a S or memorizer can do, or be taught to do, to process or encode material for more efficient retrieval. This section will deal with coding strategies used in learning single associations and lists of verbal items. A later section deals with how verbal materials may be hierarchically arranged in memory for efficient retrieval.

REVIEW OF SELECTED LITERATURE

Perhaps the best place to start in a discussion of efficient encoding strategies is with what people do naturally when confronted with tasks of various kinds. This, of course, relates back to the previous section on IDs in memory attributes. There is also evidence on this matter from other sources. It is Jensen's (1968) and Rohwer's (1968) opinion that one major difference between good and poor learners is the degree of development of verbal-associative attributes during learning. There is some evidence that younger children and and children from low socioeconomic families in particular are lacking in these kinds of responses to material being learned (Jensen, 1968). Such children when prompted to make responses of a verbal mediational nature learn more quickly and efficiently especially when the prompted verbal attributes are syntactical strings (e.g., Jensen & Rohwer, 1963). The evidence for the effectiveness of such mediational strategies in improving long-term retention is sparse, although, at least with paired-associate tasks (Olton, 1969) they do not appear to lead to improved retention.

An informal observation by Jensen (1967), however, supports the importance of the development of verbal-associative attributes in memory. Preschool children were shown a dozen common objects such as a comb, a glass, a spoon, etc., and allowed to look at them for a few minutes. The children were told to try to remember the objects. The objects were then hidden and the children were asked to name as many as they could. Usually only three or four objects could be recalled by each child. The children were capable of naming each object when it was handed to them, so failure to recall was not due to their inability to give names to the objects. If, however, the children were required to give a name to each object when it was first presented to them, their memory improved to eight or nine objects recalled. Jensen suggested that the visual image of the object fades quickly. What a child most easily remembers from such a situation is his own verbal responses to the objects. Older children did not benefit from such prompting, evidently because they spontaneously named the objects themselves. However, as suggested above, even older children may lack the necessary verbal responses when confronted with tasks of a verbal nature. Further research on instructing children to develop verbal mediators and the effect of the development of such verbal attributes on long-term retention is needed.

Another direction that research on efficient encoding strategies might take is the study of free-recall verbal learning. The free-recall task provides a useful paradigm for this type of research because this task imposes few constraints on Ss in terms of the memory attributes they may develop. The free-recall task is also a useful vehicle for studying ways in which Ss impose meaningful organization on material to be retained. Studies of efficient encoding strategies with such tasks may lead to useful suggestions for instructing students in strategies to be utilized in school-learning tasks.

It has been shown rather decisively by Tulving (1964), Mandler (1967), and others that free recall and amount of organization imposed on the material by Ss are directly related. According to Miller (1956) the number of separate pieces or bits of information which can be handled by the memory system at any one time is limited to about 7 plus or minus 2. Thus, in order to remember information which has many more items than this are to be learned, the S must group or organize information into about 5 to 9 pieces, variously referred to as "chunks," "categories," or "units," etc. When Ss are given a list of words to study and recall in any order, the order in which the items are recalled reflects the S's tendency to organize the material into clusters or chunks. When the list already contains an obvious experimenter-defined basis for organization (for example, the words are instances of common categories) the recall is higher than when lists do not contain an obvious organizational basis. Also, the words from such organized lists are recalled in concept clusters (Bousfield, Cohen, & Whitmarsh, 1958). Tulving (1964) has shown that when lists do not contain an experimenter-defined structure, Ss tend to construct their own basis for organizing the list into chunks. The number and stability of such chunks increases over trials as does the Ss' recall.

The basis for the formation of subjective-organization units is probably to some degree idiosyncratic; however, it should be possible to determine in the case of identifiable units what characteristics of the material (what attributes) were used by a S in encoding the items together for storage. The basis for some units may be the S's verbal responses to the words in the list. That is, words which elicit the same associative or conceptual verbal response during learning may be organized into a single chunk or unit by the S and tagged with the concept label or associative term which all the words in that unit elicit. In recall the conceptual or associative attribute serves as a retrieval mechanism for the individual items. The organization of an entire list of words may consist of a number of such associative or conceptual clusters. However, other attributes may also serve as the basis for organizational units. For example, a S may group some items because they are acoustically similar, others because they occurred in contiguous positions in the input list. Orthographic similarity (initial letter, number of letters, syllables etc.) may form the basis for other clusters. The images elicited by several words may form the basis of other clusters. Nonverbal affective responses could serve as a basis of organization for still other units. The assumption being made here is that Ss can and do use these and probably many other attributes as a basis for forming organizational units. If this assumption is true, and if these different bases for organization can be identified, then the question can be raised as to the relative efficiency of different attributes as a basis of organization in terms of long-term retention for the list. An approach that might be used to study these questions is a combination of two methodologies, that of Bruner, Olver, and Greenfield, et al. (1966), in studying modes of category or equivalence formation and that used by Mandler (1967) in studying the relationship of organization and free recall.

Several procedures were used by Bruner, et al., in studying the basis on which equivalence or conceptual groupings are formed by Ss of different ages. In one procedure, Ss were given the task of telling how different items are alike. For example, in one task the S was presented with the words banana and peach, each typed on a white card and spoken aloud. The S was asked to tell how banana and peach are alike. Then potato was added to the list and the S was asked how potato is different from banana and peach and how banana, peach, and potato are all alike. Then meat was added and the same questions were asked. This procedure was continued until the array of words consisted of banana, peach, potato, meat, milk, water, air, and germs. As items were added to the array they became more diverse, but all items shared a common characteristic, i.e., ingestibility. Other arrays of words such as bell, horn, telephone, radio, newspaper, book, painting, and education were used. The responses of the Ss were recorded and a classification of the bases for equivalence used by the Ss was derived from the data.

In another task, Ss were presented with a 6 x 7 array of pictures of common objects. From the array, Ss were to select pictures that were alike in some way and remove them from the array. When a S had completed a grouping

he was asked to tell in what way the objects in his group were alike. The pictures were placed back in the array and S was asked to form another group. This procedure was repeated 10 times with each S. Again, the responses of the Ss were recorded and a classification of types of equivalence formation was made.

Since the items in each task differed from one another in a number of different dimensions, a variety of different characteristics could be used as a basis of equivalence. The Es identified five main modes of equivalence as, perceptible, functional, affective, nominal, and fiat equivalence. In perceptible equivalence, the S rendered the items alike on the basis of immediate phenomenal qualities such as color, size, shape, or position in time or space. In functional equivalence, the S based his judgments of similarity on the use or function of items, either what could be done with or to them. In affective equivalence, Ss rendered items alike on the basis of the emotion they aroused or on his evaluation of them. When a S used the nominal basis of equivalence, he gave a common name or label for different items. In fiat equivalence, the S merely stated that certain items were alike without giving further reasons even when prodded.

Bruner, et al.,were mainly concerned with how the bases of equivalence used by Ss changed with age. Thus, they found that perceptible equivalence decreased with increasing age and functional and nominal equivalence increased. The main feature in the Bruner, et al., procedure of interest here is their technique of letting the S tell his basis for grouping items. Although they do not report data concerning the reliability of their classification system, the responses of the Ss at each age level presumably showed enough communality for such classifications to be made.

Consider now Mandler's (1967) procedure for studying organization and free recall. Subjects were given decks of cards to sort, each card bearing a single word. The Ss were given sucessive sorting trials until they had achieved two identical sorts. Subjects were not allowed to put one card into one category and all others in another, but apart from this restriction any method of sorting was allowed. Following their last criterion sort, the Ss were asked to write on a sheet of paper all the words they could remember. The materials used varied from experiment to experiment but can be characterized as a group of words from 52 to 100 in number from a wide range of Thorndike-Lorge frequency. Most of the words were nouns, about half of which also had verb functions. Since Mandler's main interest in these experiments was in the relationship of number of categories to number of words recalled and the number of words recalled per category, he restricted his analyses to Ss using no more than seven categories. He felt that it would have obscured these relationships if the task had also included the aspect of category recall. In general Mandler found, within the range between two and seven categories, a linearly increasing relationship between number of categories used in free sorting and number of words recalled. This relationship was independent of the amount of time it took Ss to form stable categories.

PARADIGM FOR RESEARCH

If one is interested in studying the relationship between the attributes a S uses to form categories and the recall both of categories and items within categories, then a procedure which requires S to form categories, tell the basis on which he formed different categories, and recall the items categorized seems appropriate. With verbal materials Ss could be given a deck of 50 or so cards containing words. They would then be given sorting trials on which they were required to sort the words into categories on any basis they wanted. The free sorting trials would continue until a criterion of category stability was reached. After the sorting trials Ss would be required to explain why each word was put into a particular category, i.e., the Ss would be asked to tell how the words in each category were alike. After a retention interval, the Ss would be required to recall as many of the words as they could. A record of the number of categories, the items in each, and the basis of each category would be kept. A classification system describing the types of categories formed by Ss could be abstracted from the data. Hopefully, this classification system would capture the attributes into which items were encoded and grouped together for storage in memory. The efficiency with which different types of categories and items within different types of categories are retrieved could then be obtained from the recall data.

In all of Mandler's (1967) experiments, retention for the words was taken immediately after the Ss had concluded their sorting trials. Mandler did, as an afterthought, retest some Ss after retention intervals varying from one-half week to 15 weeks. Mandler found that delayed recall dropped sharply in the first 3 or 4 days to about 50% of immediate recall

and reached a stable level of about 20-30% after about three weeks. This forgetting curve seemed to resemble that for meaningful connected passages rather than memory for lists. Using a single word recalled from a category as an index of category recall, the percentage of categories recalled dropped from 98% in immediate recall to about 75% after six weeks. Thereafter, category recall stabilized at about 50-60%. Mandler argues that the persisting memory for the list over 15 weeks is to some extent, due to the high percentage of recall for the coding categories. There is, however, a rather large loss of the categories over retention intervals of a week or more. One purpose of the type of experiment proposed earlier would be to explore the relationship between type of coding category and long-term retention for the category. Certain attributes initially used to form categories may be forgotten more rapidly than other attributes. Thus, differential forgetting of types of categories may be found.

The type of testing situation might also be varied. Subjects could be given cues based on the attributes which they reportedly used to form their categories. This cuing at the time of recall would be expected to improve recall. Mandler and others (e.g., Tulving & Pearlstone, 1966) have found that, given categories of a constant size, once a category is recalled (one word recalled from a category is the criterion of category recall), a constant number of items are recalled from that category. Or, given categories which differ in size, once a category is recalled, a constant proportion of the items in that category are recalled. This invariance in the number of items recalled from a category once the category itself is recalled has been found with adult Ss. There may be grounds for suspecting that this constancy will not be obtained with younger Ss. That is, with younger Ss even when categories are available (under cued condition) the number or proportion of items recalled from categories of the same size may vary.

One can consider, as have Bruner, et al., the syntax of equivalence or category formation as distinct from the mode (attributes used) of category formation. Older Ss almost invariably form categories of a superordinate kind where items are placed in a category because they all exhibit the same characteristic, e.g., all are names of food, all sound like _____, all have initial letter a and two syllables, etc. Thus the syntax of the categories is the same, superordinate, but the mode of the categories differs. Younger children more often use what Bruner, et al., call complexive structures in which attributes are used to form local rather than universal rules for grouping. Bruner, et al., distinguish several types of complexive groupings. For example, "collections" are complexes in which a single attribute is used to group items but not to tie them together. For example, a child might group items such as bell, horn, telephone, and radio because "bell is black, horn is brown, telephone is blue, radio is red" (Bruner, et al., 1966, p. 76). Thus, a perceptible attribute is used in grouping, but the grouping is not superordinate in structure. Another type of structure is a "key-ring" complex in which the S takes one item and links others to it by choosing attributes which relate the central item to the others. For example, a child may group house, hammer, nails, barn, tree, and clock because "you use hammer and nails to build a house, the barn and the tree are next to the house and the clock is found in the house" (p. 83). "Associations" are another type of complexive structure in which a link is made between two items and then the bond between these two items forms a nucleus for adding other items. For example, a child might group boots, cow, and gloves because "boots and gloves are made of leather and you get leather from cows" (p. 83).

There does seem to be an overlap between the attributes used in category formation and the syntax of the categories. Bruner, et al., report that when nominal and functional categories are used the grouping is almost always superordinate. When perceptible attributes are used, the groupings tend to be more complexive. In any case, the ease with which items are retrieved from categories of differing syntax would intuitively appear to differ. This aspect of encoding and organization in memory could also be studied by means of the paradigm described earlier.

The objective in studies which might be carried out along the lines indicated would be to explore the relationship, if any, between long-term retention and organizational or encoding strategies with the hopes of identifying relatively efficient encoding strategies. A study by Bach and Underwood (1970) showed some evidence for differential forgetting of attributes used by Ss in encoding single verbal units for memory. The informal study by Jensen mentioned earlier in this section suggested a difference between attributes in retention. A study recently conducted by the author (Ghatala, 1970) showed a differential rate of forgetting of attributes, again in the single unit situation. Because differential forgetting of attributes is shown in these situations, one might expect differential forgetting of organized material when the bases of organization are the attributes into which memories for single units can be analyzed.

IV
SECOND-ORDER STORAGE AND RETRIEVAL PLANS

In the previous section the bases for organizing a verbal list into smaller chunks which then serve as the memory storage and retrieval units were discussed. One might call the situation where the cue for recall of the items in each chunk is the attribute which served as the basis for formation of the grouping, a first-order retrieval plan. This section deals briefly with how Ss remember the chunk or category labels themselves; that is, with what might be called a second-order retrieval plan.

Bower (1970) suggests that an optimal strategy for learning the category labels is to categorize the category labels into broader but fewer superordinate categories. If this categorizing continued recursively, a set of nested sets would be generated. There are many natural hierarchies based on class inclusion rules. For example, minerals can be classified as metals or stones; metals can be classified into rare, common, or alloys; platinum, silver, and gold can be classified as instances of rare metals. In the same fashion, stones can be classified into precious or masonry, with numerous instances of each. Such hierarchical trees have a simple construction rule and Bower suggests that such a construction rule can serve as a retrieval plan, when a person is trying to reconstruct the words from memory. An experiment was done by Bower, Clark, Winzenz, and Lesgold (1969) to determine whether Ss would use a hierarchical inclusion rule of this sort in generating their recall and if so whether it would give them an advantage over Ss recalling the same word lists but without knowledge of the structural rule. In the experiment Ss learned four 28-word hierarchies concurrently (a total of 112 words to be learned and recalled). Half of the Ss were presented with the words organized into four complete hierarchical trees like the mineral hierarchy described above. The control Ss were presented with the words arranged into the same spatial trees, 28 per slide, but the words at each position in the trees were randomly selected from all levels of the four class hierarchies. Thus, for the control Ss the lists of words had no obvious structural principle. After all the words had been presented, the Ss were required to recall as many as they could in any order. The Ss having the organized presentation recalled three times as many words as the Ss having random presentation. Furthermore, the Ss in the organized condition were using the list-construction principle as a retrieval plan; their recall was entirely clustered by the class categories. In 90% of the cases where a superordinate word and some of its subordinate words were recalled, the superordinate word was recalled first. Also, a superordinate word appeared to serve as a cue for recall of subordinate words. That is, the probability of recall of a subordinate word was much higher if its superordinate word was recalled than if the superordinate word was not recalled. This conditional relationship between levels of the hierarchy was not present in the recall of the Ss receiving the random presentation. Additional control Ss were asked to try to generate the word lists from knowledge of the list construction principle. These Ss performed very badly, thus ruling out sheer guessing as a factor in the superior performance of the Ss receiving the organized lists. Bower concludes from these data that the organized lists give Ss a systematic retrieval plan. However, the retrieval plan operates under the constraint that words generated by it must be checked for recognition of list membership before they are overtly emitted in recall.

The existence of such retrieval plans can also be ascertained in a more naturalistic setting than the usual laboratory situation in which lists are presented for learning. If individuals are asked to generate items of a certain type from their permanent long-term storage, evidence for hierarchical groupings is found. For

example, Bousfield and Sedgewick (1944) have shown that when Ss are asked to list all the birds they can think of they produce these in clusters of subcategories. This finding suggests that recall from permanent vocabulary storage follows the same organizational schema as the assignment of specific words in a memory experiment.

Mandler (1967) has suggested that memory is organized into hierarchically arranged categories. He assumes that the basic limit of processing at each level of the organization is 5 ± 2 units. This limit represents a refinement of Miller's (1956) previous estimate. Thus, at the first level one can have 5 ± 2 categories each with 5 ± 2 items per category. When the first-order categories are filled up, a second level of categories will be formed, each of which can contain 5 ± 2 first-order categories and so on. The limit to the number of levels in the hierarchy is again 5 ± 2. Thus, the memory units available in such a schema is 5^5, not an exceedingly large number. However, Mandler speculates that memory may be organized into more than one schema and that a still higher level of schema may exist. Again, applying the limit of 5 ± 2 to the levels of schemata, results in an estimate of $(5)5)^{5)}$ units which could be stored. This is an exceedingly large number.

It appears that what both Mandler and Bower are discussing under the term "organization and memory" is really the organization of the human verbal repertoire as it exists fully developed in adult Ss. Conditions of input and recall will certainly affect the memory for verbal material, but it is largely the organization of the verbal repertoire which limits what can and will be recalled. It would seem that what needs to be studied is the development of this verbal organization in young children.

V

SUMMARY AND IMPLICATIONS FOR EDUCATION

In this paper the conceptualization of memory as consisting of a collection of attributes was explored. Underwood's (1969) work on attributes of memory was reviewed. Following this, several paradigms for further research were suggested. One research paradigm dealt with individual differences and memory attributes. It was suggested that individuals may well differ in the extent to which they develop or utilize certain types of attributes. The paradigm suggested for exploring such differences was to look at individuals' performance across a number of tasks thought to reflect the development of certain types of attributes.

If it turns out that individual differences in attributes can be identified reliably by the method of correlating performance on such laboratory tasks, then further research to determine the importance of this "learning style" variable in instruction would be necessary. It may happen that individual difference variables reflected in such "artificial" laboratory tasks may have no relation to learning in a school setting. However, it is the feeling of this author that the subject variables identified in this manner may be very basic to the school's learning process. For example, subjects who are good at producing visual images may be distinguished from subjects in whom this encoding skill is not well-developed. Also, individuals who develop strong associative and conceptual attributes during learning may be distinguished from subjects who do not. These differences may well be related to the ease or difficulty in learning certain subject matter or in learning from different modes of instruction.

The recent move toward individually guided education in the nation's schools must surely call for a better understanding of how students differ not only in ability but in learning style and how instruction can be tailored to the ability and style of each learner.

A second research paradigm dealt with the types of organization imposed by a subject during the learning of a list of verbal items. Research by Tulving, Mandler, and others was reviewed. This research suggests that with supraspan lists of items, Ss group items together into chunks which then become the storage and retrieval units for the list. The organization of a list into about seven chunks is presumed to occur because of limits on subjects' ability to process information. The work of Bruner, et al., on the development of modes of equivalence formation was also reviewed. The research paradigm which was suggested consisted of a combination of Mandler's (1967) and Bruner's (1966) methodology whereby subjects are required to group a large number of words into categories (Mandler), explain the basis of his categories (Bruner), and then recall the items categorized. From the category data a classification system describing the types of categories formed by Ss would be developed. Hopefully, this classification scheme would capture the attributes into which the items were encoded and grouped together for storage in memory. The efficiency with which different types of categories and items within different types of categories were retrieved could then be inferred from the recall data. It was also suggested that the syntax of categories be explored. Research with adult subjects has shown an invariance in the number of items recalled from a category once the category itself is recalled. Evidence was cited from Bruner, et al., which shows that in children of different ages, different types of category structures are used which differ from the superordinate structures preferred by adults. Perhaps the item-per-category recall would change as a function of the structure or syntax of the category. Finally, it was suggested that conditions during recall be manipulated. Tulving (1968) has suggested that the

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organization of material in the memory store does not necessarily increase the storage capacity but rather makes the stored information more accessible to recall by providing distinctive retrieval cues. This notion implies that there is potentially more information available in the store than is typically recalled in unaided recall tests due to loss of retrieval cues.

This problem can be studied within the paradigm described above by providing some subjects with cues based on the attributes which they reportedly used to form their categories prior to recall. Performance of these cued subjects could be compared to subjects receiving irrelevant cues or no cues.

The implications of this type of research for education lies in its emphasis on searching for the methods that subjects use to acquire material of certain kinds. With the paradigm discussed above it should be possible to determine the more efficient approaches to organizing material of a specific kind under specific task requirements. As Tulving (1968) has pointed out this type of research underscores the need to examine the methods that learners in classrooms use to acquire knowledge and skills. Perhaps the good teacher is one who organizes the material to be learned in a way which optimizes learning and retention. Such optimal organization for various kinds of material could perhaps be identified and used to create efficient programs for learning. More importantly, the learners themselves could be instructed in how to learn and how to remember so that they can become independent of the teacher or the program.

The final section of the paper dealt with higher-order storage and retrieval plans. The work of Bower (1970) on the construction of recursive schemata for recall of hierarchically organized categories was discussed. It was pointed out that studies of organization and memory in adults are really dealing with the organization of the human verbal repertoire. Conditions of input and recall may affect the memory for verbal material by activating certain portions of the existing verbal schemata for use as storage and retrieval plans. What needs to be studied more intently is the development of this verbal or conceptual organization in young children.

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